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ARS
SPECIAL
REPORT

Dwarfing Plants With Chemicals

A Promising Agricultural Technique

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To the reader:

This report was written primarily to provide background information for Extension and other agricultural leaders in answering growers' questions on chemicals as aids in keeping plants from growing too tall or too fast.

These chemicals for achieving plant compactness are promising, but are still mainly experimental. At least one, phosfon, has reached interstate sale for use on commercially grown chrysanthemums. More are in prospect, to serve additional purposes.

Put in perspective: Chemicals cannot substitute for genetic breeding in achieving permanently dwarfed varieties. But chemicals can dwarf many plants for a lifespan, thereby providing useful additions to dwarf varieties now available. And chemicals can be managed flexibly to hold down stem height of selected plants, or to hold back growth at an inconvenient time.

Information in this report was provided by the Crops Research Division, Agricultural Research Service

DWARFING PLANTS WITH CHEMICALS-- A Promising Agricultural Technique

Chemicals as braking tools, to hold back stem growth of a plant and halt it at a desired height, are among the newest plant regulators that research is developing and trying out to serve practical needs.

This research is in line with a strong modern trend--toward increasing demands for compact plants by crop growers, home gardeners, and the flower-buying public.

Overtall crop plants and flowers, sky-reaching trees, and shrubs that need frequent pruning are common, often costly, problems that growers would like to overcome--always provided the taming of nature can be managed without loss of yield or other bad effects in a plant.

Chemical help with such problems has looked promising since 1949. That year, plant scientists in the U. S. Department of Agriculture reported the first success in using organic chemicals to dwarf a test plant without harm to the plant.

In the 12 years following, they have screened many more chemicals as prospects and have tested the most effective compounds on diverse farm crop plants and ornamentals. Lately, they have carried the task forward to develop practical treatments for a few selected plants.

Scientific interest in this new way to dwarf plants is broadening. Chemical research is increasingly developing new compounds directed toward this kind of plant control. Experimental work in testing and applying these chemicals on plants is in active progress in research agencies across the country, including those of industry. The goals are in the direction of finding treatments that are effective on more kinds of plants, and that are cheaper and most practical in all respects for a given purpose.

This report presents mainly some highlights of the work with these plant-dwarfing chemicals by the USDA Agricultural Research Service, either alone or in cooperation with other agencies, with a little general information for background.

USES, PRESENT AND FORESEEN

Overall reduction in plant height is the predominating effect of the growth-retarding chemicals described in this report. Along with this effect there is often some slow-down in the plant's growth rate--a delay in flowering, a prolonged life span. Since both the size effect and the growth rate effect are adjustable, many uses have been recognized for compounds of this type.

Florists are the first growers to have opportunity to use chemical tools for dwarfing a commercial crop, to provide a desirable compactness. Commercial products are discussed on page 12. Varied uses for this agricultural technique are now being studied and some have reached trial stages. Among the many uses that have been suggested are these:

- To improve the form and attractiveness of many kinds of tall-growing flowering ornamentals.
- To shorten stem height of crop plants that are subject to wind damage--a cause of troublesome lodging or seed-shattering.
- To shorten stem height of certain crop plants to facilitate harvesting.
- To overcome excessive stem length in an otherwise desirable crop variety--a problem in some bean varieties, for example, and in fruit and ornamental vines.
- To retard or stretch out the rate of development in selected plots of a planted crop, such as beans, to extend production through the season from a single planting.
- To slow down the growth of trees that tend to interfere with overhead power lines--to save expensive pruning.
- To limit stem height of shrubs and other outdoor ornamentals--to keep plantings in proportion to small lots or to low-roofed houses, such as today's ramblers and ranch-type homes.

HOW ARS EXPLORATORY WORK HAS ADVANCED

Discovery of Dwarfing Effect

The first satisfactory dwarfing of a plant with chemicals was achieved by ARS scientists in 1948 with nicotinium compounds applied to the Black Valentine snap bean. Research scientists had previously dwarfed plants chemically as early as the 1930's, but the short-stemmed plants showed damage and their yields of grain or fruit were low.

In the break-through experiments, six nicotiniums moderately suppressed the stem growth of potted bean plants, and the plants remained healthy-looking. The most active of the nicotiniums shortened bean stem height by about a third.

A Particularly Encouraging Chemical

In 1950, ARS scientists reported that six quaternary ammonium compounds were far more potent for successful dwarfing than the nicotiniums previously tried. The most active ammonium compound shortened plant height by fully two-thirds.

The experimenters named this quaternary ammonium Amo-1618. Later, they tried 80 quaternary ammoniums in comparison with it and found none more active.

Though only a few test plants besides chrysanthemums showed marked responsiveness to Amo-1618, this chemical had the special significance of putting chemical dwarfing on firmer ground. Knowing that one chemical could be so successful with some plants, researchers could expect to find compounds for adjusting a wide range of heights in many kinds of plants, even those not readily susceptible to chemicals that had been tried on them.

The Test Program Extended

The program of testing retardant chemicals has been extended since to include a number of types. Among the thousand or more compounds for regulating plant growth that chemical research has developed thus far, several hundred have been tried out for their effect on limiting stem growth.

Promising sources have been found among compounds built around quaternary ammoniums, such as sulfonates, carbamates, and cholines; also among the phosphoniums, which contain phosphorus as their key ingredient instead of nitrogen as in the others mentioned.

Among the newest encouraging prospects are choline derivatives. Although choline itself is inactive on stem growth, certain compounds derived from it hold down stem growth and with substantial advantages. One of these derivatives has limited stem height in an unusually large assortment of test plants, including some species that had been unresponsive to compounds of many kinds.

Table 1 gives several examples of compounds that have been used in ARS research. Cited are the full chemical name and the short name or research number that chemists or plant scientists have conferred on the compound for convenience. Some distinctions of each compound are indicated.

Table 1.--A Few Plant Growth Retardants Used Experimentally by the Agricultural Research Service

Full Chemical name	Short name[1]	Some indications for use
2-Isopropyl-4-dimethylamino-5-methylphenyl-1-piperidinecarboxylate methyl chloride	Amo-1618	A potent dwarfing compound from which much has been learned about plant height control; outstanding for chrysanthemums and a few other plants.
3-Isopropyl-4-dimethylamino-6-methylphenyl-1-piperidinecarboxylate methyl chloride	carvadan	Closely related to Amo-1618, this compound has dwarfed some plants that resisted other chemicals, including poinsettias that had not responded favorably to 100 other compounds.
2, 4-dichlorobenzyltributylphosphonium chloride	phosfon	A compound very similar to Amo-1618 in effectiveness for dwarfing chrysanthemums; also effective in experimental work on lilies and petunias.
(2-chloroethyl) trimethylammonium chloride	CCC	A choline derivative, promising for dwarfing many flowering plants, also some foliage plants and trees.

[1] A short name is often adopted by research scientists to refer conveniently to a much-used chemical. In ARS records, Amo-1618 was the 1,618th compound tested for regulating plant growth in some way. Phosfon is the name ARS scientists have used for the most active phosphonium they have tested, the only phosphonium they have used extensively in this work.

CHEMICALS IN TRY-OUTS ON TEST PLANTS

Learning What a Chemical Can Do

In exploratory research on growth-limiting compounds, ARS scientists have followed procedures similar to those used in studying stimulators, such as the gibberellins that spur plants to faster and taller growth.

Preparations. For testing on potted seedlings, the pure chemicals are mixed in solution, paste, or dry form. Commercial formulations of plant-regulating chemicals ordinarily contain filler or other substance to facilitate use, and this is allowed for in the manufacturer's directions for making a dilute spray or other application. In experimental work with pure chemicals, ARS scientists make a solution by dissolving the required amount of the growth-regulating chemical in warm water. A small amount (0.1 percent) of a wetting agent or spreader[1] is added just before use.

Selected treatments. Initial tests are precision treatments, in which a measured quantity of a chemical is applied to a small section of stem, the midrib of a leaf, or another selected plant part. Many groups of seedlings in pots are grown for each test, always with some untreated plants for comparison. Besides application to plant parts, treatments include soaking or dipping cuttings or roots before planting; mixing a solution in pot soil; drenching soil after growth is started; and spraying solution on growing plants.

Strength. Activity of the chemicals and plant receptivity differ greatly. In one series of tests on many kinds of plants, 4/10 gram of the mildly active CCC was comparable to phosfon at levels of 8/100 to 3/1000 gram. These figures give an idea merely of dosage ranges. Plants react so distinctively to retardant chemicals that one species' or variety's reaction is no guide to another's. Any successful treatment is necessarily tailored to a particular plant and a specific purpose.

Experimental treatments range from weak to strong, to learn the most effective dosages, and also the consequences of too much or too little. With retardant chemicals, doses too weak are either ineffective or have the unexplained effect of stimulating growth. Doses too strong induce slight, if any, additional suppression of stem growth, and an overstrong dose may delay flowering long beyond any desirable date. Moreover, an overdose of some retardant chemicals is toxic, causing leaves to yellow or wrinkle, flowers to be defective, or in some cases causing death of the plant. From an economic standpoint, either underdosage or overdosage is a waste of the chemical material.

Application method important. How a treatment is applied has proved more important with retardant chemicals than with growth-stimulating chemicals. Some height-limiting treatments have been successful only when soil-applied.

Duration of influence on plants. An effectively treated plant may remain under the influence of a chemical briefly or for a lifetime. Repeat treatments are sometimes advantageous.

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[1] Wetting agents serving this purpose are a type of detergent used in washing dishes and sold under trade names--a type chemically composed of polyoxyethylene sorbitan monolaurate. In experiments described in this report, Tween 20 has been the detergent most frequently used for convenience. Mention of this detergent does not constitute an endorsement by the U. S. Department of Agriculture of this product over similar products or a guaranty or warranty of the standard of the product.

Lastingness of chemical activity. A striking characteristic of at least one of the more active retardant chemicals is its long-lasting activity.

Low dosages of Amo-1618 have remained active for 10 years in ordinary clay and sandy soils. The evidence: 30 generations of short-stemmed plants grown successively in these soils after one initial soil treatment. The generations of plants showed progressively less dwarfing as the chemical was used up.

As a check test, bean seedlings have been planted recently in soil that was treated 10 years ago with Amo-1618 and held in a moist condition in a greenhouse. Seedlings grown in this soil developed excessively short stems.

Amo-1618 or some byproduct also retains activity for a considerable time in seeds. Bean plants grown in treated soil have conveyed the dwarfing effect to their seed pods, and the seeds have transmitted it to progeny plants. These chemical-carrying seeds have dwarfed three generations of plants.

ARS scientists have had enough phosfon and CCC--two of the more recently studied retardant compounds--to make some soil tests. Phosfon has influenced five consecutive crops of a test plant. CCC influenced one crop only.

Plant Reactions to Effective Treatment

When a retardant chemical works well on test plants, growth takes this characteristic course:

- The outstanding change is a shorter length in each developing section of the stem between nodes (joints). The stem also thickens, sometimes becoming almost twice its usual diameter. A treated plant tends to become compact and sturdy.

- Leaves that develop after treatment are often deeper green and thicker than the plant's usual foliage.

- Blossoming is sometimes delayed--in bean plants 3 to 10 days. Flowers develop normally, sometimes are more vivid in color.

- Maturity of bean plants has lagged as much as a month following treatment.

- The slow-down of growth lengthens the life span of a plant--in bean plants as much as 40 days.

The younger the plant when treated, the more influence a retardant treatment can exert on overall height and the plant's rate of development.

Suiting Chemicals to Crop Plants

Chemicals found most active on original test plants have been used by ARS scientists in further systematic studies to test the reaction of representative crop plants, from field crops, vegetables, and fruits, to shrubs and flowers.

Plant species, and even varieties, have been remarkably selective in the retardant chemicals to which they respond. Unlike the generally responsive bean, many plants have responded encouragingly to a few compounds or only one.

When Amo-1618 showed special promise in bean experiments, it was tried on 50 crop plants. It reduced stem height markedly in only these: bean (bush lima as well as snap), calliopsis, chrysanthemum, lettuce, sesame, and sunflower.

A slight change in a compound may change entirely the effect on plants. One isomer of Amo-1618--that is, a certain rearrangement of the same atoms of the molecules--has increased the activity of the chemical. This isomer, named carvadan, has induced stem-shortening in some plants that could not respond to Amo-1618.

One phosphonium has dwarfed a number of plants that had responded to other compounds slightly, or not at all.

In a study reported in 1958, thirty new quaternary ammonium compounds were applied to 12 test plants: balsam, mung bean, Scarlet Runner bean, snap bean, buckwheat, cotton, cucumber, marigold, peanut, soybean, sunflower, and sweetpea. Several of the 30 ammoniums dwarfed all 12 to some extent, but in general the most effective compound was different for each kind of plant.

How differently a series of test chemicals may affect the same plant is illustrated by the row of chrysanthemums in figure 1. Out of four retardants, two worked well, one damaged the plant, and one induced no change.

The further point that one plant's reaction is no guide to how other kinds may react is illustrated by the row of white zinnias of Purity variety in figure 2. This variety took the extraordinary turn of growing half a foot taller than normal on a phosfon treatment, and was dwarfed to a third of normal height on the choline derivative CCC.

A search for retardant chemicals best suited to slow-growing woody and foliage plants has been started at the ARS Plant Industry Station, Beltsville, Md. Phosfon and one or two other compounds have shown some promise for suppressing growth of arborvitae, holly, mimosa, euonymus, and a few other shrubs and trees. More effective and possibly more economical treatments are hoped for.

In this study, 22 kinds of woody plants and 18 kinds of foliage plants are being tested on soil treated with phosphonium, ammonium, carbamate, and choline compounds. Long-term effects will be observed first in the greenhouse and later in the field.

All studies of the kind described in this section lead toward research on specific crop problems. A few examples of this applied research by ARS plant scientists follow.

ORNAMENTALS AS PACEMAKERS

Flowering ornamentals are pacemakers in showing what man can do, and may hope to do, with chemicals to keep valued plants from growing too tall or too fast. Ornamentals are taking this lead for combined reasons:

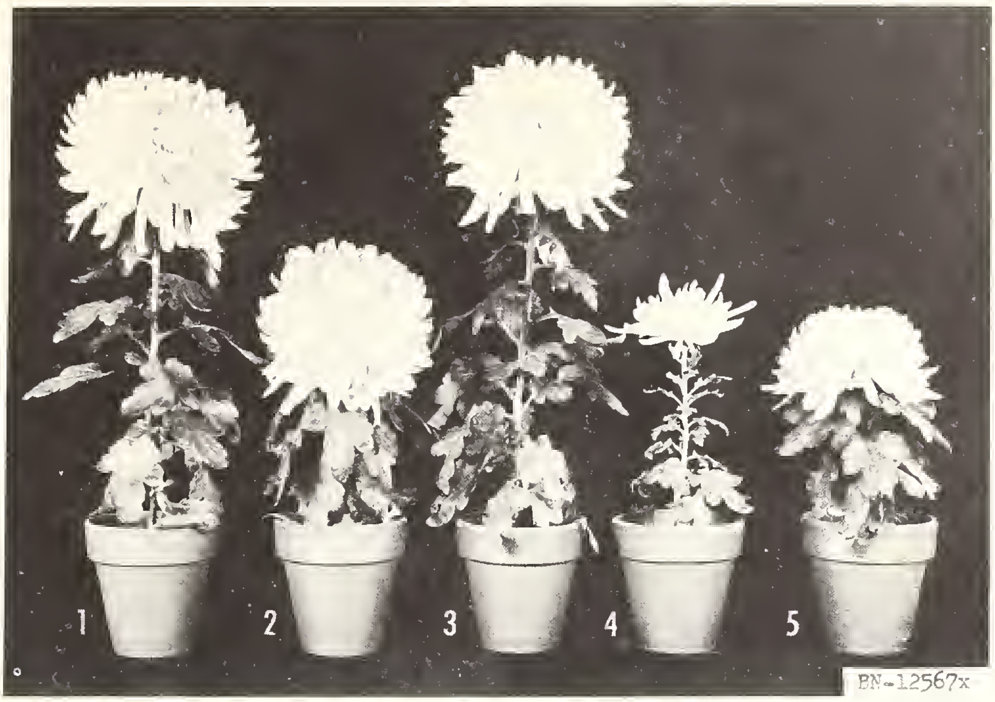

Figure 1.--The chrysanthemums pictured are of the same variety and age. Plant No. 1, standing about 15 inches tall, was grown untreated. The other four plants were grown in soil treated with 8 milligrams of different test compounds. Plant No. 2 treated with Amo-1618 was attractively compact. Plant No. 3 treated with a carbamate known as CIPC showed no reaction at all. Plant No. 4 treated with another, unnamed carbamate showed damage in its stunted leaves and blossoms. (Its root growth failed.) Plant No. 5 treated with phosfon developed attractive compactness, shorter than No. 2.

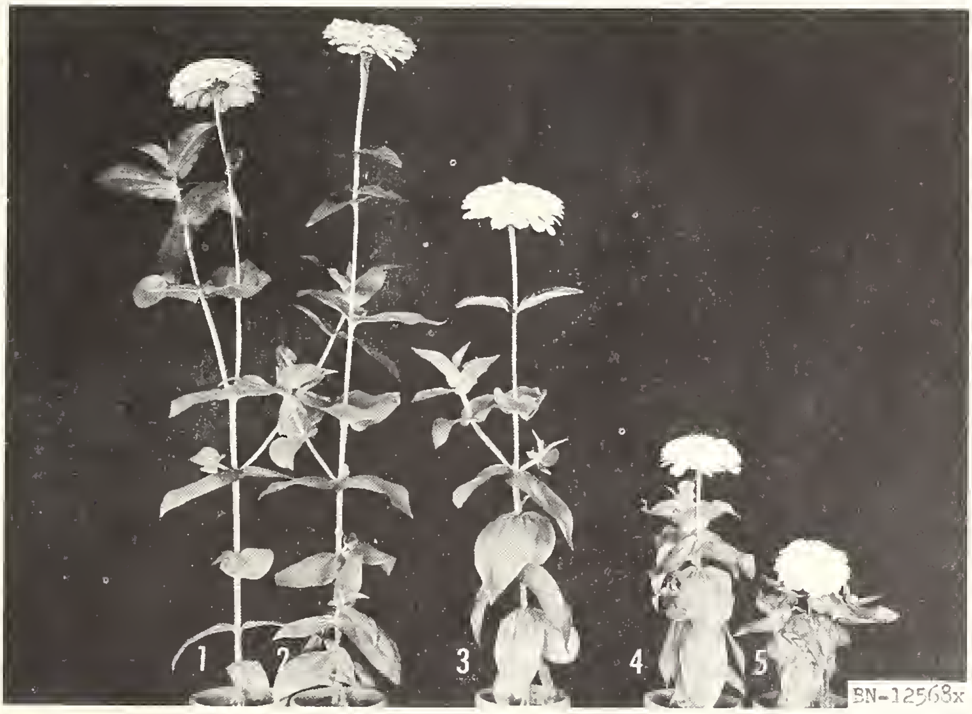

Figure 2.--The untreated control plant in this zinnia group, No. 3 at center, reached 3-foot height. Plants No. 1 and No. 2 at its left unaccountably grew taller than normal on phosfon dosages of two strengths. The more strongly dosed plant attained 3½-foot height. Plants No. 4 and No. 5 at right meanwhile developed compact dwarfed form on CCC, No. 5 receiving the larger dose.

- In preliminary research, tall flowering plants showed outstanding promise for dwarfing.

- Treatment of an ornamental can be brought to practical use stages faster than treatment of a food or feed crop, in which the possibility of any harmful residue would have to be investigated for the safety of man or animals.

- Research on selected ornamentals can aid one agricultural group, the florist industries, in improving their products or production efficiency. At the same time, ornamental research provides information that may be applied in developing chemical treatments for farming, landscaping, and home gardening.

What Successful Treatments Can Do for Ornamentals

Since 1957, ARS plant specialists have done considerable research on chemical dwarfing of chrysanthemums, lilies, and some other ornamentals. Successful treatments show varied practical merits, primarily these:

Many attractive varieties that normally grow too tall for satisfactory pot flowers can be chemically dwarfed to desired heights. With this height control, florists may have a larger selection of plant forms and colors from which to choose the best for mass pot plant production or cut flowers for sale.

Chemical treatment often improves the general appearance of floral plants beyond compactness and pleasing proportions. Leaves are often a deeper green. Color of flowers is sometimes brightened. Poinsettias better retain their lower foliage as an effective green setting for the red or white bracts.

Chemical treatment can substitute for much of the laborious pruning and training that florists now have to do to produce compact plants that consumers want.

For landscaping and gardening, some of the same advantages would solve problems and are in prospect. Chemical treatment can save some pruning and staking labor, and hold some garden varieties of tall flowering plants to heights that suit a border or the proportions of low-roofed or small houses. Selectively applied, chemical treatment can hold down the height of some of the plants in a group for a graduated effect.

Chrysanthemums

Amo-1618. In tryouts of more than 100 compounds, 28 suppressed stem height of chrysanthemums to some extent and, of these prospects, Amo-1618 was outstanding. This chemical, experimentally applied to rooted cuttings as a dip or soak, caused chrysanthemums to grow very short stems and bear full-sized blossoms. The dwarfed plants were pronounced ideal for small, well-shaped potted flowers.

So little Amo-1618 was available in 1958 that the ARS Pesticide Chemical Research Laboratories undertook to synthesize 100 grams.

Part of this large sample was allotted to chrysanthemum research. Intensive work with Amo-1618 at the Plant Industry Station has shown that--

- Every variety of chrysanthemum tested has responded by stem shortening to some extent.
- Some varieties could be dwarfed a great deal; some only a little. The most sensitive variety tested, Fred Shoesmith, could be dwarfed down to 7-inch stem height.
- Strength of a treatment needs always to be adjusted to the variety and also to the degree of dwarfing desired, within the plant's own limits.
- Delay in flowering is part of the retardant effect. The stronger the treatment, the later flowering will begin. After 25 p.p.m. (parts per million) treatment, rooted cuttings of Fred Shoesmith chrysanthemums grew 11-inch stems and flowered in 76 days. (Untreated plants grew 15-inch stems, and took 68 days to flower.) After 100 p.p.m. treatment, the same variety grew 7-inch stems and took 78 days to flower. This was practically the limit for dwarfing this variety, but not for retarding its bloom. After 400 p.p.m. treatment, plants took 95 days to blossom.
- Dwarfed plants concentrated their stem growth on the main stem, without branching.
- Peduncle (flower stalk) growth is shortened if the retardant is applied as a spray when flower buds become visible. This treatment can improve the floral display of mum varieties that normally grow overlong flower stalks. The treatment does not alter flowering time.
- Applying Amo-1618 to the soil is the easiest method of using it to dwarf chrysanthemums. Water solutions have been effective either when mixed with the pot soil or poured on the soil as a drench.
- Mild doses of this chemical for dwarfing pot chrysanthemums can be applied either before or after cuttings root. Stronger doses are best applied after rooting, because a pre-rooting treatment slows root growth and lessens effectiveness of the chemical on stem growth.
- Chrysanthemum plants treated with this chemical respond to long and short days just like plants untreated. Management of light in greenhouse conditions is the same.
- Amo-1618 has good keeping quality. Prepared solutions stored for 7 months at 40° F. retained their effectiveness for retarding plant growth.

Phosfon. After work with Amo-1618 started, a newer chemical, called phosfon by research scientists, was so effective on chrysanthemums in preliminary tests that the two compounds have been compared in varied experiments. Although the two are considerably different chemically, treatment with either one retarded chrysanthemum plants similarly.

One difference has been found in successful management of the two chemicals:

Though soil treatment is the easiest way of applying Amo-1618, it can be applied to any part of the plant without causing damage, however strong the dose.

Soil treatment is the only practical way of applying phosfon. Spraying it on plants or dipping cuttings in it has destroyed chlorophyll and even killed some chrysanthemum test plants.

Directions for specific uses of a manufacturer's formulation would take into account such findings as those described and other findings from research.

Poinsettias

Although poinsettias responded scarcely at all to Amo-1618, a single change in the compound has produced a chemical that can successfully dwarf a tall-growing poinsettia variety down to half or a fourth of its normal height.

This compound, which ARS scientists named carvadan, is an isomer of Amo-1618. Chemically, the two compounds are composed of the same three major parts. But one of these essentials--the terpene ring--is derived from thymol in Amo-1618 and from carvacrol in the isomer.

While much that has been learned about dwarfing chrysanthemums can be applied to poinsettias, the poinsettia plant has its individual responses and requires some special adjustments to its ways of growth. Major differences are these:

- In chemically dwarfed poinsettias all parts of the plant are scaled down in size. The "flowers"--actually the leaflike red or white bracts--are slightly smaller, also fewer, than on the same variety untreated. In a "pint-size" poinsettia pot plant, this overall dwarfing maintains good proportions.

- Treatment does not delay the flowering of poinsettias.

- Lower leaves stay on the plant throughout flowering.

For commercial poinsettia growers, one advantage of retardant treatment may be to release them from a time problem. Early cuttings that are taken in July and August are always too tall at flowering and are often useless. These cuttings may be used for single-stemmed short plants by dipping them in carvadan solutions. In experiments, the earlier the cuttings were taken, the stronger the dosage needed. To obtain maximum dwarfing, some of these plants required 2,500 p.p.m. of the chemical. Far weaker dilutions were adequate for dwarfing cuttings taken late. Carvadan has caused no toxic damage to poinsettia plants when applied to the soil or the plant in varied ways.

Lilies

Experiments indicate that stately lilies can be chemically dwarfed to adapt them to more varied decorative uses. Easter lilies of the cut flower type, even those growing 4-foot stems that suit only church decoration, can be made over into superior pot lilies, short and compact. Garden lilies that grow overtall can be held down in height likewise. Some of the garden varieties when shortened would be suitable as new types of pot lilies for indoor flowers. Two chemicals have given encouraging results.

By managing timing and applications, ways of using phosfon to dwarf lilies are being developed. Among many materials tried out on lilies, this chemical was the most effective, but at first it presented a problem. The lilies required heavy doses of phosfon to hold back stem growth, and these amounts applied at potting time caused some lilies to develop limber stems--due to an increase in cell size and a reduction in cell wall thickening in a layer of cells that normally provide stiffness in lily stems. The simplest way found to overcome this problem has been to apply a drench on the soil around the plant when stems reach active growth stage, and just before flower buds are visible. Foliar spray can be an alternate treatment, provided another chemical is combined with phosfon to inhibit leaf damage. Among the chemicals that can serve in this way as an antagonizing agent, one is sodium-potassium chlorophyllin.

CCC, on which work has lately been started, is a much less active chemical than phosfon but is effective for controlling stem height of lilies when larger doses are used. The treatments with CCC must be soil-applied, since foliar sprays have shown little effect. CCC treatments, however strong, have not caused limber stems in lily plants.

Hydrangeas

The florists' hydrangea is another example of a popular pot plant that often grows overtall. Until choline derivatives were tried recently, ARS scientists met with no real encouragement for chemical dwarfing of hydrangeas. Phosfon held down stem height, but caused damage to the hydrangea plant's leaves. Good results on hydrangeas, however, have been attained with CCC used as a soil drench. Foliar spray of CCC appears to be effective but must be repeated several times. These hydrangea experiments are still in early stages.

ENVIRONMENT IMPORTANT TO SUCCESS WITH CHEMICAL DWARFING

Environment is proving to be a major key to success with chemical dwarfing of plants. Early exploratory work was focused almost entirely on what the chemicals could do and how plants responded. Now, the life story of the compact plant has been rounded out by tests showing that it is no freak or self-sufficient prodigy. Dwarfed by a proper chemical treatment, the pint-sized plant is essentially normal and is influenced by environment like any full-sized plant.

Diagnostic Tests Show Normalcy

Petunias have been used as test plants for learning whether a chemically dwarfed plant that looks well is actually normal in its relationships to environment. The petunia's evidence is that a compact plant follows orderly growth habits. It is guided by photoperiods (day lengths) and other ordinary light requirements to begin flowering. It reacts normally to temperature, moisture, and soil nutrients and fertilization--indicating normal dependence and requirements. Such evidence means, for example, that the chemically dwarfed plant requires watering and fertilization as often and as heavily as any similar untreated plant. Its flowering time can be hastened or slowed by adjusting light conditions, and also temperature.

Petunia case histories show, in brief, that a successful retardant treatment confines its significant change in the plant to holding down stem lengthening, not interfering with nutrition or altering vital processes. When the retardant chemical extends its influence to deepen leaf color or to scale down blossom size, these few side effects are within range of the normal--far different from the damage sometimes induced by an excessive dosage.

Special Starting Prescriptions

The compact petunia's normalcy led ARS scientists to the idea that special advantages at the nursery stage might give such plants unusually good form and readiness for gardens. A special starting prescription could combine a chemical retardant treatment with several environmental controls--all consistent with favorable natural growth.

Success with these experimental prescriptions adjusted to several petunia varieties has indicated that combination treatments of this kind may overcome a spindly growth problem in a number of garden flowers. Some well-liked varieties of flowering annuals are problem plants because they are set out commonly in spring for early summer flowering, and the long days and short nights that speed flowering also cause these varieties to develop one long, weak stem to support all of a plant's leaves and blossoms. Commercial growers who provide the seedlings can induce branching by pinching off main stems, but this does not check the tall growth.

The following procedure, found well-suited to the tall-growing Ballerina petunia, gives some idea of a combination treatment:

A retardant chemical treatment was applied to the soil at the time the seedlings were shifted from small to larger pots after root growth was well started. This treatment held Ballerina plants down to desired height. Meanwhile, from seed-sowing time, the light allowance was limited to 10 hours daily by use of dark cloth shades, and this induced seedlings to branch in 6 weeks. At this stage, flowering could be speeded by lengthening the light allowance to natural day length of more than 12 hours, either in daylight or with aid of incandescent bulbs.

Temperature is one more factor to be considered, in adjusting a treatment of this kind to a desired effect. Warm nights (70° F.) speeded the Ballerina variety's flowering, whereas nights only 10 degrees cooler retarded its flowering. However, the variety formed more basal branches when given 60° F. nights.

COMMERCIAL PRODUCTION

As this report goes to press, at least one chemical for dwarfing an ornamental has reached interstate commercial sale under trademark. The compound that research workers call phosfon, which the manufacturer supplied for plant experiments, has been officially registered for height-retardant use on chrysanthemums grown in commercial greenhouses. Manufacturers are working toward marketing some additional promising chemicals named in this report, such as Amo-1618 and CCC, or others with dwarfing potential. No chemical for this type of overall height control has been Federally registered thus far for use on a food or feed crop.

Dwarfing Chemicals Subject to Laws

Manufacturers are required to market retardant chemicals for ornamentals under the same laws that safeguard other chemicals sold for agricultural uses. Any such chemicals sold interstate must be cleared through the U. S. Department of Agriculture as to their effectiveness for the stated purposes. When all requirements are met on a label prepared for a product, the Department registers the label. The acceptable wording for uses, limitations, cautions, and directions must accompany the product in interstate commerce. Many States have similar procedures for approving agricultural chemicals offered within State lines.

USE BY PLANT BREEDERS

Geneticists have begun to make practical use of dwarfing chemicals.

Amo-1618 is being used as an aid in breeding new soybean varieties at the ARS Plant Industry Station. In winter greenhouse conditions, plants such as soybeans develop overactive, thin stem growth. This tall growth hampers the geneticist who would like to grow more normal plants and concentrate more test pots in each bench unit for easier tending. Amo-1618 has been found capable of dwarfing these experimental plants to 50 percent or less of usual height without altering other characteristics. This use of chemicals is being tried on some other crop plants.

A quite different advantage that geneticists expect to gain with such chemicals is to control flowering time in a more convenient way. In developing new hybrid varieties of crops such as corn and sugarcane, crossing requires bringing slow- and fast-flowering varieties to pollen stage at the same time. Outdoors, this has always called for troublesome successive planting. Indoors, some of this multiple planting can be avoided by controlling light to alter flowering dates. Some of the newer chemicals, such as CCC, give promise of making one planting serve, either indoors or out. With the right chemical treatments, fast-growing varieties can be held back to flower at the pace of the naturally slow-flowering varieties.

LOOKING AHEAD

The search for effective and economical chemicals that can dwarf plants in useful ways undoubtedly will continue. The mildly active CCC, which can dwarf many kinds of plants and is short-lasting in soil, gives encouragement for finding practical dwarfing treatments for food and feed crops.

How rapidly progress comes in making the best possible use of plant growth regulators, including dwarfing chemicals, depends to a great extent on learning more about basic plant physiology. Little is known as yet about how and why these chemicals operate as they do in plants. Research scientists hope to learn more about how an applied chemical is absorbed and translocated by a plant, and how the chemicals work with natural chemicals and microorganisms in the plant. With further knowledge of such processes and relationships, plant scientists can avoid much of the slow trial testing now required in developing useful crop treatments, and they can provide growers with directions geared to a new and more precise efficiency.

Growth Through Agricultural Progress

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